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Quarterly Progress Report No. 18
1 March 1979 to 31 May 1979

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This document describes progress on development of a packet radio network. Activities reported include work on Station Software and Internetworking Research and Development.

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1. INTRODUCTION

An important component of the Packet Radio project is the station software, providing a variety of control, coordination and monitoring functions. BBN's role in developing this software is to specify, design, implement and deliver programs which perform these functions.

During this quarter important progress was made on design details in the processing of Local Repeater On Packets (LROPs) and Performance Data Packets (PDPs). These and other meetings and negotiations are covered in section 2, especially noting important demonstrations of mini-gateways, Transmission Control Program (TCP), and down line loading of Packet Radio units by the station. Section 2 also covers publications, including two important Internet Experimenters' Notes on routing and flow control.

Section 3 deals with the Packet Radio network area, especially station issues, and is dominated this quarter by the completion of coding of the Channel Access Protocol (CAP) version 5 Labeler process. The CAP 5 Labeler has been partially tested and debugged, and is now working in the BBN PR net testbed. Additional progress of lesser import was made on the PR down line load process, the cross-radio debugger, and operating systems ELF and MOS.

Section 4 covers the installation of a new service host machine for TCP testing and development. Also in section 4 is a discussion of improvements in the robustness of mini-gateways, and demonstrations of mini-gateways.

Section 5 reports on a number of hardware issues which evolved during this quarter. Of most significance is the conclusion of the investigation into problems with Error Control Units (ECUs).

2. MEETINGS, TRIPS, PUBLICATIONS

2.1. Meetings and Trips

A number of meetings this quarter furthered technical design and negotiation in several areas. A software review meeting for the Improved Packet Radio (actually held the last week of the preceding quarter) was attended by BBN personnel. Here the design of the IPR operating system was fine-tuned to best support project needs.

BBN personnel were on site at SRI for pre-demonstration preparations the week before the March 27 demonstration of the network, as well as during the demonstration. At this event the new PR down line load capability was demonstrated, as well as TCP functions and general CAP 4.9 operation.

A technical design meeting of CAP 5 implementers, held April 9-11 at ARPA facilities in Washington, was also attended by BBN personnel. Here details of Local Repeater on Packet (LROP) and Performance Data Packet (PDP) processing were resolved. Schedule issues were also negotiated, and packet formats specified. Station resources will be freed by having either a measurement process, or cross-radio PR debug and PR down line load processes, but not all three, resident simultaneously. The most important improvement which CAP 5 will achieve is the change to point-to-point routes, which will alleviate the congestion now seen at the station's PR destined for the resident gateway.

We hosted an Internet meeting in mid-May, at which we demonstrated gateway alternate routing. Gateways at BBN were configured such that two paths existed between a TIU on the BBN Research Computer Center network and a TIU on the SRI Packet Radio network. When one path was broken, by halting one of the gateways on that path, traffic was automatically routed by the gateways over the alternate path. This demonstrates the

operational function of the new gateway alternate routing strategy presented in our previous QPRs. (See especially QPR 17.)

2.2. Publications

Three important publications were released this quarter.

PRTN 174 - revision 7, "Packet Radio Network Station Labeling Process"

This PRTN has been updated to include the latest modifications to the Labeler as modified for CAP 4.9.

Internetwork Experimenters' Note (IEN) 86, "Extended Internet Routing"

IEN 87, "Internet Flow and Congestion Control"

These two IENs present designs in dealing with complex issues in internet traffic handling. While the latter attempts to prevent collapse of performance when offered traffic threatens to exceed the capacity of internet components, the former provides mechanisms for properly delivering traffic while the network is constrained by access control requirements. IEN 87 covers more than just access control, however; it presents a method of providing routing which recognizes qualitative differences among links. Access control implies just keeping "bad" traffic off a given link; extended routing provides that and in addition allows users to avoid links with certain characteristics for the users' own reasons as well, or to weight against the use of those links.

We also contributed additional material to the Packet Radio project bibliography this quarter.

2.3. Negotiations and Informal Documents

2.3.1. Periodic route erasure

PR route handling was partially redesigned at the PRWG meeting last quarter, January 22-24. In talking about the new approach afterwards at BBN we found an unfortunate impact on CAP 5 routing, as noted in QPR 17. As discussed there, a small change to PR route erasure has important consequences. During this quarter resolution was reached on this issue, as described below. For context, the statement of the issues is also presented again here.

Decision at PRWG Meeting

- PR only erases a route if it needs the slot for a new route.
- PR keeps track of route usage by a time stamp and will not erase the route until its lack of use goes over a certain threshold.
- PR will erase the route which has been used least recently if a slot is required.

Problem

If the TIU is only interested in sending packets to a few destinations some routes may rarely, if ever, get garbage collected. Since the CAP5 station will try to reassign routes traveling over a bad link, rather then simply erasing them, a significant portion of station resources may be tied up keeping track of and updating old, unused routes.

Suggested approach

We suggest that two thresholds be used for decisions about route discarding. The first, and current, is the minimum time before the PR can optionally garbage collect an unused route slot for a new route. Its purpose is to provide slots for new traffic so the traffic won't be forced to funnel through the station which is both slow and costly.

The second threshold is the maximum time an unused route should be allowed to remain in the PR's route table. After this threshold is reached route erasure is mandatory regardless of need for reuse of the slot. The purpose of the second threshold is to reduce control traffic and route computation by the station. The mandatory route erasure would be a much longer time interval than the optional route erasure. Perhaps on the order of minutes for optional, and on the order of hours for mandatory.

Why it works

The station won't realize the route has been erased because the mandatory erasure is based on time since last use rather than time since creation, and will retain knowledge of the route until there is a problem on one of the links. At that time it may choose to send out a new route. It will then be informed that the route is absent from the PR and will erase the route from the station's own table.

This approach limits the useless control traffic to one exchange. If the route hadn't been removed, the station would continue to compute new routes for the PR.

Resolution

The eventual resolution of this problem occurred in the middle of March, and is as follows:

1) A PR will erase a PTP route 1 hour after the route's last use if the PR can open an SPP connection to the station. The PR will send a reason dependent PDP over the SPP connection indicating that the route is erased.

2) Unlabeled PRs maintain link quality tables through normal LROP processing. As soon as the PR is labeled, the PR will send a PDP to the station reporting current link qualities.

3) Raw transmit counts will be included in all PDPs. These will be used to evaluate the PRs' capacity, and when understood, may impact routing algorithms to aid in congestion control.

4) PRs will immediately generate a link quality change PDP if the link quality falls below a certain level.

5) PRs will not immediately report the removal of a route to make room for another, but wait until a PDP is generated for another purpose.

6) The Labeler will send route interrogation packets to correlate its understanding of current routes with those actually distributed. We must still consider the impact of patching the Gateway PR to accept some large number of routes (30-50). This will require more then one packet from the Gateway to report all the routes.

7) There will be no indexing into the PR's route table. (This has no direct bearing on the PTP route erasure but was negotiated at the same time.)

2.3.2. Miscellaneous negotiations

Many informal negotiations this quarter revolved around the resolution of CAP 5 design issues. In preparation for the CAP 5 meeting (see section 2.1), we developed the rough plan for a mechanism to support better alternate routing. This consists of a "help" packet sent by a mobile PR which can no longer send (get acknowledged) its traffic. Unfortunately, the cost of maintaining information sufficient to get traffic addressed TO the mobile PR delivered is high. We also prepared a list of CAP 5 issues needing resolution.

We reviewed data from UCLA which showed some loss of Cumulative Statistics (CUMSTAT) packets from PRs and TIUs during measurement experiment runs UCLA conducted. We concluded that

excessive congestion in the network could explain all the effects shown, and, since we know there is congestion difficulty with CAP 4 protocol, we assume that that is the proper explanation.

An internal document was drafted this quarter, explaining how to deliver station software to remote sites using the cross-internet debugger, XNET. This will help streamline the delivery of station software in the future, permitting more rapid and reliable operational support in this area.

We continued the informal investigation into PR radiation hazards, begun last quarter. We sent further figures on the PR's microwave radiation level, and its relation to United States and Russian safety standards, to Collins and ARPA. It would appear that whether safety standards are violated by workers near PRs is arguable; the radiation is neither negligible nor obviously a serious danger.

In early April we hosted a visit from Professor Dimitri Bertsekas of MIT, at which we discussed his "contingency" routing algorithms. These seek to establish a new path to a common destination when links in the network fail. We talked about their features and their possible applicability to the Packet Radio net. We received from him a paper on his design, "Algorithms for Optimal Routing of Flow in Networks", another related to Professor Gallager's routing scheme (see QPR 16, section 2.1.4), "Validation of Algorithms for Optimal Routing of Flow in Networks", and a copy of the thesis of Michael Hluchyj, one of Professor Gallager's students, "Connectivity Monitoring in Mobile Packet Radio Networks". We considered these, but in each case one or more of the features of the Packet Radio net which make the net attractive, also make it intractable by the theoretical mechanisms considered.

These features are primarily:

(1) potential link between any two nodes,

(2) moderately frequent disruption of each of several links (especially due to mobility of PRs),

(3) point-to-point routing desired, rather than concentration to or from any one point,

(4) importance of relatively speedy repair of broken routes, though absolute optimality is unnecessary,

(5) inability of nodes (PRs) to perform large computational tasks, and/or to store large volumes of data, and

(6) interconnection of many logical links, due to use of shared radio broadcast channel, making channel bandwidth used for control on various links more costly.

In mid-May a PR failure (see section 5) prompted us to note certain problems with the PR software. The "hardware straps" diagnostic seems to assume certain RAM memory locations - not initialized by the program - contain valid data. If the diagnostic is run with different data than assumed, it does not execute properly. This was reported to Collins. Also reported was a problem with the text of LROPs, but since this problem could not be reproduced after repair of our failed PR, we ascribe it to hardware malfunction.

We negotiated two PDP issues with Collins personnel. In one, we discussed whether receipt of a down line load request from a neighbor PR should constitute a new PDP "reason" entry. It was resolved that the present mechanism, which includes a reason entry for unlabeled neighbors, contains sufficient data to also convey the down line load request, with a slight reformatting. The second issue regards when PDPs may be sent

without connection close (FIN) indication. One suggestion is that PDPs be sent as "normal" (versus SYN/FIN) if either the receive or the transmit sides are open. Presently only the transmit side is tested. As this quarter closed, this issue is still under discussion. The important issue here is that the station and the PR not become confused about the state of the connection between them. If they get out of synchronization, undesirable delays may be incurred and control traffic may be lost. We are also in contact with Collins about actual debugging of PDP transmission via SPP.

3. THE PACKET RADIO NETWORK

3.1. Station Programming and Testing

3.1.1. ELF, MOS

Three improvements to the ELF operating system were made this quarter. The first is that ELF now jumps into the internet bootstrap code after system errors. This will allow the crashed ELF memory image to then be accessed remotely via XNET, the cross-internet debugger, with no manual action at the station site. This will aid debugging, which was hampered by the fact that programming staff could not connect to the ELF once it crashed without co-ordination with on-site personnel. Additionally, this permits another step we have taken to aid debugging; a command file has been written which allows an inexperienced operator to dump the ELF memory image into a TOPS-20 file after system errors.

Second, the ELF system has been modified to not use XNET debugger packets destined for the Packet Radio net to identify itself. To preserve software interchangeability, ELF does not have its network address compiled into the program. Instead, it used to listen for the first XNET packet it received, and use the address of the destination specified in that packet as its own address. Unfortunately, the new process used by SRI to load Terminal Interface Units (TIUs) on the PR net, uses XNET to perform the load. If a fresh station first receives TIU load packets, the address ELF takes as its own is incorrect; in particular, the network number is that of the PR net, not the ARPANET. Thus further communication via XNET fails, and in particular the TIU load attempt fails. ELF was modified to take its address only from packets not destined to a PR net, which preserves the interchangeability and solves the problem.

Third, a bug in ELF's IMP11-A interface driver was found and fixed. This remedies a long standing, obscure problem in its input/output system.

Also a bug in MOS was fixed this quarter, in the teletype device tables. MOS is the operating system used in mini-gateways.

We also worked on station software configuration to support the March 27 demonstration (see section 2.1). This involved adjusting system resource allocations to provide good service for the loading that was anticipated.

3.1.2. Labeler

The CAP 4.9 Labeler was revised this quarter to suppress labeling attempts instigated by ROPs containing down line load requests. Since the PR was not running CAP protocol, such attempts were doomed to fail anyway. This would also cure a problem reported by SRI, wherein the Labeler went deaf for a period of many minutes to a PR which was being down line loaded but taking a long time for the load. With this particular problem, however, it appears that bugs in the PR CAP 4.9 code were to blame.

Coding of the CAP 5 Labeler, which requires extensive modifications to the CAP 4.9 version, were completed and tested this quarter. The size of the Labeler has actually decreased, which is good news considering the tightness of station memory. This decrease is due partly to removal of old routines pertaining only to CAP 4 logic, and partly to alteration of data structures to provide more compact storage and cheaper referencing. The savings is one page of memory. Although future enhancements may reuse this page, the decrease is an encouraging fact.

Some CAP 5 Labeler debugging was performed on the PDP-10 this quarter, because the PDP-11 was in use for Internet meeting demonstration preparations (see section 2.1). The routines dealing with route computation were extracted and modified to PDP-10 BCPL, and debugged with BDDT. Although these routines were the only ones which could be made machine-independent (since others performed extensive input/output manipulations), debugging them on the PDP-10 used the time well which would otherwise have caused a slip in delivery. This is due to the complexity of these routines, arising largely from the need to carry not only number of hops but also accumulated route quality through the computations.

The CAP 5 Labeler is now working in the BBN PR net testbed. It labels both PRs, receives PDPs on both specific and listening connections, and generates PDP requests when appropriate. As this quarter draws to a close, the plan is to now move to further testing in the SRI net with its larger population of PRs. Since CAP 5 supplies information not previously available, we also plan to add new manual entry commands to the Labeler to permit the station operator to make use of this data.

In summary, CAP 5 provides the following new features:

+ LROPs assess radio link quality locally
+ good neighbor table (GNT) in each PR stores its current connectivity
+ PRs use GNT to provide more reliable alternate routing
+ PRs report connectivity (GNT) and exception conditions to station via Performance Data Packets (PDPs)
+ PDPs are sent via reliable protocol (SPP)
+ Labeler uses PDPs to maintain a station table of link qualities

+ Labeler can request a PDP when necessary
+ Labeler employs link qualities as well as route length (number of hops) to assign routes
+ failure of traffic is reported in a PDP, resulting in timely assignment of a better route by the Labeler

3.1.3. PR down line load process

During this quarter, a bug in PR down line loading was fixed, and one performance improvement was made. An additional problem in down line loading was found to relate to PR code, and was cured by a later release by Collins.

The bug in the station's PRLOAD process was a failure to correctly detect the connection process' occasional, temporary inability to open a connection to a loader PR, a PR through which the final hop of a down line load is performed. This could occur when the connection process was momentarily too busy -- or out of connection slot resources -- to honor PRLOAD's request for a connection. The result was a hangup of down line loading. The problem was fixed by improving the connection handling error routines in PRLOAD.

The improvement to PRLOAD performance resulted from a more detailed consideration of the handshaking which occurs in down loading the station's PR. As discussed in QPR 17, there is no loader PR when loading the station's PR. therefore, there is no SPP connection. It had been thought that with only a raw (non-SPP) connection, PRLOAD might overrun the connection process or the station's PR, feeding it down line load packets faster than they could be processed. Closer consideration, however, revealed that with a connection window size of one, the connection process will not accept from PRLOAD (and thus cannot transmit to the PR) another packet until the previous packet has

been transmitted successfully. Removing the rate-limiting timer from PRLOAD now permits loading the station's PR in only three seconds, compared to four seconds for a PR one hop from the station, and nine seconds for the old method of loading the station's PR.

Also during this quarter we sent documents to SRI, describing various aspects of down line loading and in particular how to use the support software to place a TOPS-20 disk file of PR software on the station disk. It is our hope and expectation that Collins or SRI staff will be available to follow these procedures, thus preventing delivery of PR code to station disk from relying on availability of BBN staff.

3.1.4. XRAY cross-radio debugger

Joint debugging with Collins this quarter permitted the release of a completed new version of the cross-radio debugger, XRAY. This version uses command packets, performs multiple alter memory (AM) and multiple display memory (DM) commands properly, and employs 20-bit addresses to support IPR memory size. This version also includes a new command, the DL command, which forces the target PR into down line load mode. The delivery of this version of XRAY included updated documentation.

A command to send an "initialize" packet to the target PR was tried. This packet commands the PR to perform an initialization sequence similar to that resulting from an operator pushing the "INIT" button on the PR manually. The code in XRAY to permit this, however, bumped the XRAY memory requirements across a page boundary. The new XRAY would require slightly over one, and therefore two, pages of station memory. The station memory resource is in short supply; also, SRI commented that the new DL command will obviate the need for a remote initialize command. Consequently, the "initialize" command was not retained in XRAY.

3.2. Support

During this quarter we made a preliminary investigation of modifying the BBN "PRU" program to use a Pluribus TIP (PTIP) line. This would allow Collins to debug BBN PRs remotely without having to borrow one of the scarce direct terminal lines on a service host. The BBN PRU program was derived fairly simply from the original PRU program written at SRI, but conversion to use PTIP line(s) is significantly more complex. The host-PTIP dialog for line allocation, buffer management, and especially for speed selection is significantly more complex. Since these operations are scattered throughout the PRU program, a relatively tricky and large modification is necessary. Also, execution of the host-PTIP dialogue requires that the job run with certain privileges enabled, and letting remote, non-BBN personnel run a job so enabled is likely to encounter administrative objections from computer center staff. Nevertheless, the modification appears feasible if programmer time is available.

Another support activity this quarter has been delivering PR CAP software to station disks at SRI and BBN. The following chart summarizes these deliveries.

CAP version	to BBN	to SRI	to tape cassette
4.9.5		X	
4.9.6		X	
4.9.7		X	
4.9.8	X	X	
4.9.9		X	
5.0.0	X		X

These deliveries, of course, are in addition to regular deliveries of station software.

Also this quarter we created a directory on BBN system C, for SRI to use in exercising TCP.

4. INTERNETWORKING

4.1. Transmission Control Program (TCP)

During this quarter important strides were taken in providing a more practical environment for developing, debugging, testing and exercising TCP and Internet Protocol. This is a TOPS-20 system, now named BBNF. TCP version 4 has been brought up on this machine, on which arrangements with ARPA have been made to provide very significant amounts of stand alone test time. Bringing up TCP 4 is considered to be part of the acceptance testing of the machine.

The first connections between a Terminal Interface Unit (TIU; the ALTA-COMA TIU at BBN in particular) and BBNF, running TOPS-20 release 3A with TCP and TELNET protocols in the monitor, were made this quarter. Having these protocols handled in the monitor provides faster service to the user and requires less overall time for the same results. The operation of connections demonstrates a high degree of accomplishment toward the goal of providing monitor resident TCP and TELNET to other sites. As this quarter closed, the closing code (no pun intended!) for TCP virtual terminals is in final stages of debugging; completion of TVT debugging is anticipated early next quarter.

4.2. Gateways

Elaborate testing and demonstration of mini-gateway functions was performed this quarter. First was a complex test at SRI. The configuration was as follows.

(1) The mini-gateway was run in the SRI PDP-11/34 as a host on the ARPANET and on the Packet Radio net.

(2) The station, with gateway and TCP, was run in the SRI PDP-11/40 as a host on the Packet Radio net only.

(3) The station was then disconnected from the ARPANET.

Three resulting data paths were demonstrated, as follows.

(1) Users at SRI were able to connect to STACON, operator's terminal control module in the station, from the TCP at BBNC, via the mini-gateway and the TCP in the station.

(2) Users could also connect to STACON from a Terminal Interface Unit (TIU) on the SRI Packet Radio net, through the TCP in the station.

(3) TIU users could also connect through the mini-gateway, and from there through the TCP in the station, to STACON.

Later this quarter, in mid-March, we demonstrated the mini-gateway, running in a PDP-11/40 at BBN, connected between the ARPANET and the BBN Research Computer Center (RCC) network.

Problems surfaced in the robustness of the mini-gateway to withstand errors on the 1822 interface ready line. The mini-gateway was modified to withstand such errors, and tested in two ways. First, the cable between the IMP11-A (the PDP-11's 1822 interface) and the IMP was plugged and unplugged. Secondly, the mini-gateway was further tested by running two Internet traffic streams through it for several hours.

Various versions of the mini-gateway were released this quarter: the version demonstrated at SRI, and the modified version resilient to ready line errors; also SATNET/ARPANET mini-gateways, which now support alternate routing and run on the smaller and more efficient MOS operating system. We also delivered to SRI a station whose gateway is configured to run only on the Packet Radio net, ignoring the station's ARPANET connection, which is still used for debugging and station PR software delivery.

Gateway functions were also demonstrated prominently at the Internet meeting, which is described in section 2.1.

5. HARDWARE

5.1. Error Control Units

The Error Control Units (ECUs) manufactured by ACC arrived at BBN for testing and diagnosis of compatibility problems last quarter. Some problems were found and fixed, but proper operation was not yet achieved. Early this quarter we hosted a visit by ACC engineers to iron out the difficulties. Severe pulse reflections from a point where two cables met were found to be confusing the ECU. Although the IMP11-A (PDP-11 interface) and Pluribus interface worked satisfactorily with this, the ECU is more sensitive. ACC engineers installed a smoothing circuit, which eliminated all errors. To test the result, station software was loaded and run, through the pair of ECUs, both connected to the Pluribus and to an ARPANET 516 TIP. The ECUs have been shipped to SRI, per ARPA's request, now that the problems are solved.

5.2. Packet Radio Units

A few hardware failures occurred in the BBN PRs this quarter, requiring on-site work by Collins engineers and some module swapping, under special one-time permission, by BBN personnel. PR number 1 suffered a DMA module failure, which first gave symptoms looking like a memory failure in the other PR. Later, a bad transmit/receive switch in PR number 1 necessitated dropping the use of the PRs from the Internet demo. Both PR number 1 and PR number 2 each suffered I/O channel card failures.

Both PRs were upgraded with EPR Operating System version 2 PROM boards, and aligned by Collins personnel for optimal radio performance. Down line loading was enabled in both PRs, permitting local testing of the PRLOAD station software and faster recovery from PR software crashes.

The two Packet Radio Digital Units (PRDUs) are no longer needed, since the EPRs are now functional. The PRDUs and associated gear were returned to Collins. We also corresponded with Collins regarding the radiation pattern and Q of the standard PR antenna. Detailed information they supplied helped us to evaluate possible microwave radiation safety hazards, as discussed in section 2.3.

5.3. PDP-11/34 Cache

As reported last quarter, SRI had raised a question about the cache in the PDP-11/34, used at SRI and planned for use at Fort Bragg. The question involves a possible lack of "transparency", in that the ELF operating system may need to execute certain instructions to enable the cache, and to field interrupts from the cache.

We requested further technical details from SRI, since the cache was one chosen by them and not a component of the standard Packet Radio station as specified by BBN. Upon receiving this information, we deduced that the cache is the standard, transparent cache and does not require modifications to the station software.

5.4. Station PDP-11s

The BBN station PDP-11 number 1 suffered a CPU failure, which was repaired by DEC, by replacing the data path board. Both PDP-11s were unavailable for a moderate interval this quarter while recabling was performed in preparation for the mini-gateway demonstration March 16.

The Collins PDP-11/34 is now operational, and we are in touch with Collins regarding details of arranging to run station software on it. This will give Collins a local PR net testbed, allowing much better checkout of PR software before release, and

mutual debugging by BBN (via cross-net debugger) and Collins (locally) when this is appropriate.

5.5. BBN Service Hosts

During this quarter, BBNA was down solidly for two days in May with hardware problems. Also slowing progress (on TCP in particular) was a rash of hardware problems on the new stand alone test machine, BBNF. These included problems with network interface hardware, somewhat difficult to separate from software (i.e., TCP integrated into the monitor) problems. All BBNA and BBNF hardware malfunctions had been corrected by the end of the quarter.